Education/Public Outreach

The Laboratory for Terrestrial Physics' Education and Public Outreach Program supports exploration and discoveries of Earth and Planetary Science through a wide-ranging outreach program to the general public. The Program is a comprehensive resource for research conducted by the Laboratory and promotes scientific literacy and awareness of Earth and Planetary Science. The Laboratory's Program aligns with NASA's education objectives to enhance educator knowledge and preparation, develop supplementary curricula, forge new education partnerships and support all levels of students. Several of the Laboratory's premier Educational and Public Outreach projects came to fruition in 2002, including:

- GLOBE (Global Learning and Observation to Benefit the Environment)
- Baltimore Student Sun Photometer Network (BSSN)
- IMAGERS (Interactive Multimedia Adventures for Grade School Education Using Remote Sensing)
- Earth as Art
- Earth as History
- MOLA: Models of Earth and Mars Topography for Classroom Use
- Classroom Activity Development
- Website Development

The Global Learning and Observation to Benefit the Environment Program (GLOBE)

Scientists in the Biospheric Sciences Branch worked throughout 2002 with the GLOBE program. Their work included the development of student protocols, outreach activities, and the use of GLOBE student data for Earth Science research. The GLOBE Program is a worldwide network of K-12 students, teachers, and scientists working together to study and understand the global environment (http://www.globe.gov). GLOBE is a cooperative effort, led in the United States by a Federal interagency program supported by NASA, NSF, EPA and the U.S. State Department, in partnership with colleges and universities, state and local school systems, and non-government organizations. Internationally, GLOBE is a partnership between the United States and 100 other countries. Over one million primary and secondary students in more than 12,000 schools and more than 20,000 GLOBE-trained teachers have taken part in the program as of December 2002, and those numbers continue to grow!

GLOBE students make observations and measurements that have been developed by research scientists on the soils, hydrology, land cover, phenology, and atmosphere at or near their schools. The GLOBE Protocols have students characterizing the soils at their site by horizon, and provide data on soil color, structure, texture, consistence, roots, rocks, carbonates, pH, particle size distribution, fertility, and bulk density. In addition, students collect soil temperature and soil water measurements. In the Atmosphere Protocol, students collect data daily on cloud type and cover, precipitation, precipitation pH, and current, maximum and minimum air temperature. For Land Cover, a Modified UNESCO (MUC) land cover classification is obtained as well as qualitative and quantitative biometric measurements (tree height and circumference, grass biomass, canopy

cover, and ground cover). The Phenology Protocol directs the students to observe the timing of bud burst and other growth milestones of local vegetation. In the Hydrology Protocol, students make weekly measurements of transparency, water temperature, dissolved oxygen, pH, electrical conductivity, salinity, alkalinity, and nitrate at a local water body.

Upon joining the GLOBE program, each school receives a 15 km by 15 km Landsat sub-image of their particular area. Using the Land Cover Protocol, students classify the imagery according to vegetation type and characteristics for "ground truth" purposes. Using GPS receivers, students determine the latitude and longitude and collect other metadata about their study sites. Students then report their data through the internet to the GLOBE data archive, and scientists use these data in their research.

As part of the GLOBE project, Dr. Elissa Levine developed the student protocols and learning activities for soil characterization that are part of the GLOBE soil investigation. These are available as part of the Teacher's Guide on the GLOBE web page (www.globe.gov). Dr. Levine and her team within the Biospheric Sciences Branch have also developed educational materials and web resources. They perform training sessions and other outreach functions for the educational community, and use the GLOBE student data for their Earth Science research. In one study, GLOBE student data for soil, atmosphere, land cover, and GPS are being used to parameterize and validate a biophysical Earth system simulation model (GAPS). GAPS (General Purpose Simulation Model of the Atmosphere-Plant-Soil System) is a menu-driven model that simulates soil, plant, and atmospheric processes (e.g. evapotranspiration, soil water flow, plant water uptake) using a choice of algorithms and robust graphical display of output. As an example, soil characterization data, as well as land cover, climate, and GPS data collected by GLOBE students from Reynolds High School, Greenville, Pennsylvania, USA, were used to parameterize GAPS. The model simulated daily soil moisture content by horizon at the Reynolds site for 1997 through 2000. The students' soil moisture data were then used to validate model simulations. In the validation exercise, the optimal simulation scenario for GLOBE data was chosen based on the best fit of the GLOBE data to model results. Results of this study demonstrate that GLOBE student data could provide an important source of input and validation information for simulation models such as GAPS and improve our understanding of the Earth system (Figure 1). Similar simulations are being performed using data from other GLOBE schools in different biomes.

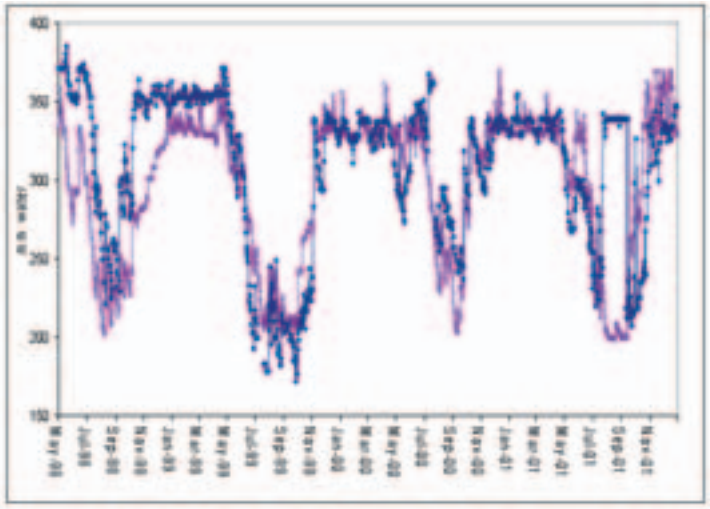

Figure 1. Comparison of the simulated and actual soil moisture content in the root zone (90 cm) (Reynolds HS, Greenville, PA, USA)

In another research project, Dr. Levine and her team compared recent GLOBE soil and water pH data with the same data collected by USEPA in the early 1980's as part of the Direct Delayed Response Program (DDRP) to determine trends in soil and water pH over the last 2 decades. This research proj-

ect focused on the DDRP data collected from the Woods Lake watershed in the Adirondack region of New York State and the Northville Central GLOBE School in Northville, New York.

Dr. Levine, Dr. Dan Kimes, and the GLOBE Soil Team also continue to investigate the relationship between soil color and other soil and ecosystem properties using GLOBE student data worldwide. In order to find the most robust model for this comparison, complex modeling techniques such as neural networks are being used. Results from this project will help scientists to better understand concepts related to soil development as well as how to use soil color as an indicator of other soil and environmental conditions (e.g. carbon content, fertility, water content, etc.).

Detailed papers describing these research projects are on the GLOBE web site (www.globe.gov).

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Baltimore Student Sun Photometer Network (BSSN)

The "Baltimore Student Sun Photometer Network" (BSSN) is an education project, related to Dr. Elissa Levine's Baltimore Asthma studies. It is funded through a grant from the Director's Discretionary Fund (DDF) at Goddard Space Flight Center. The BSSN project provides students in 20 schools throughout the Baltimore City area with hand-held sun photometers and breath peak-flow meters. These students are making daily measurements of atmospheric aerosols and cloud cover in order to relate the presence of particulates (which have been strongly correlated with asthma) to lung function on a real time basis. In addition, the student measurements will provide the first local scale characterization of particulates which will be used to validate the measurements of the Aeronet Sun photometer (located on top of the Maryland Science Center in Baltimore and part of an International network of instruments measuring particulates in the atmosphere). Results are submitted daily by students via the internet where they are stored, and can be viewed at the project website (http://bssn.gsfc.nasa.gov). Learning materials and other information are also available for students and teachers use at this website. Information from this unique project will also be fed in to our data base to increase our understanding of pediatric asthma in the Baltimore region and help improve predictive capabilities.

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The IMAGERS (Interactive Multimedia Adventures for Grade School Education Using Remote Sensing) Program

Also coming to fruition in 2002, the IMAGERS Program is NASA's comprehensive Earth science education resource for the introduction of remote sensing and satellite imagery to children in grades K-8. The Program is comprised of two multimedia web sites: "The Adventures of Amelia the Pigeon" and "The Adventures of Echo the Bat". The objective of IMAGERS is to captivate children at an early age in Earth science through multimedia adventures.

"Echo the Bat" and "Amelia the Pigeon" have two major components: (1) an interactive web site with a multimedia adventure game; and (2) an activity guide with lesson plans and reproducible hands-on activities. The interactive web sites engage children, while the supplemental materials enable educators to introduce the concepts through hands-on activities in the classroom. Applying this methodology, parents and teachers are able to teach Earth science using remote sensing imagery via identification of land use, exploration of featured habitats, and changes in the environment.

"The Adventures of Echo the Bat", originally developed in 1998, was the inaugural project of the IMAGERS Program. The web site follows Echo as he migrates through various habitats in Arizona and teaches students to understand about light and the electromagnetic spectrum as a foundation for remote sensing. The Adventure offers a directed and investigative approach to how land features look from space, what the colors mean in a satellite image, and how to identify habitats using false color. These fundamental concepts behind remote sensing science are reinforced in the classroom with a teacher's guide for grades 5-8.

Following the success of the web site, an Echo the Bat picture book was released in 2001. The book tells the story of Echo's adventure in Arizona to children grades K-4, through the introduction of the five basic concepts of understanding satellite imagery: perspective, shape, pattern, color, and texture. The book also contains an activity guide, which reinforces these concepts with hands-on activities for the classroom.

The IMAGERS project saw major expansion in 2002 with the completion of the Echo the Bat expansion to Arizona State Parks, and the launch of the Amelia the Pigeon website and teacher's guide. These two milestones, outlined below, played a crucial role in expanding the IMAGERS program to a national audience.

In the summer of 2002, Echo the Bat project was expanded again and introduced to a broader audience through an informal education project with Arizona State Parks. Located in three different geographic regions of Arizona, each location features an interactive information display, accompanied by an activity sheet. The general public (adults and children) visiting these locations are introduced to the local habitat through satellite imagery. Each of these locations have trained education specialists who interact daily with visitors and school groups and introduce the benefits of studying the environment from space.

"The Adventures of Amelia the Pigeon" was launched in the fall of 2002. The Amelia Project is the second interactive IMAGERS web site with multimedia components to engage the K-4 audience and illustrate Earth science concepts. The Pigeon Adventure presents science concepts through metaphors and analogies that relate to inner-city life. The use of a pigeon as the vehicle for the web site provides a metaphor familiar to inner-city children, and Amelia is utilized to introduce the concept of perspective. Through aerial photography created by Pigeon cameras, the web site focuses on the benefits of a bird's eye view. Throughout the interactive adventure portion of the web site, aerial and satellite imagery are used to demonstrate the advances of remote sensing through the century. Amelia the Pigeon presents new insights into habitats as she explores the urban environment of New York City.

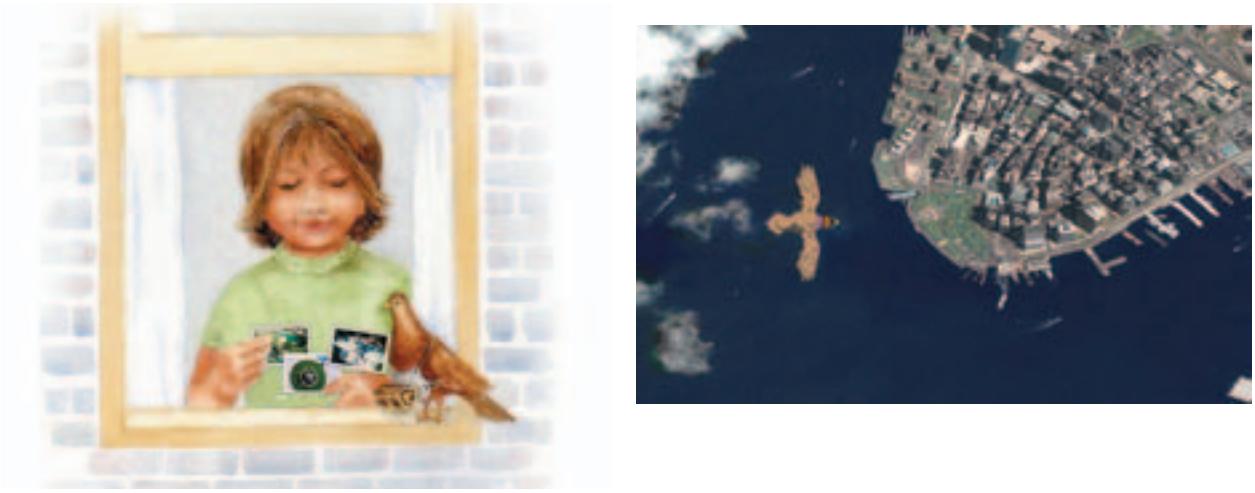

Figure 2. Scenes from The Adventures of Amelia the Pigeon. The water color artwork, at left, was done by Jean Masetti.

To learn more about these exciting projects and the IMAGERS Program at NASA, visit the IMAGERS web site: http://www.imagers.gsfc.nasa.gov/

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Earth as Art

To gain wider recognition of the public value of the Landsat Program, administered jointly by USGS and NASA, the Satellite Systems Branch at the USGS EROS Data Center created an exhibit of 41 framed Landsat images that were selected on the basis of their aesthetic appeal. These images use the visceral avenue of art to convey the thrilling perspective on the Earth that Landsat provides. With vivid colors woven into amazing natural patterns, the images connect the public audience to science and technology in basic, almost instinctive ways that differ from other kinds of Education and Public Outreach (EPO) programs.

The initial public response to these images at the local level was so positive and immediate, the decision was made in 2002 to collaborate on extending their influence to a national scale. USGS staff from the Land Remote Sensing Program and EPO specialists from NASA Goddard Space Flight Center met on March 22, 2002 to discuss possibilities for collaborating on a pilot EPO program for the exhibit. From this meeting, the USGS/NASA team developed the pilot program entitled Landsat: Earth as Art.

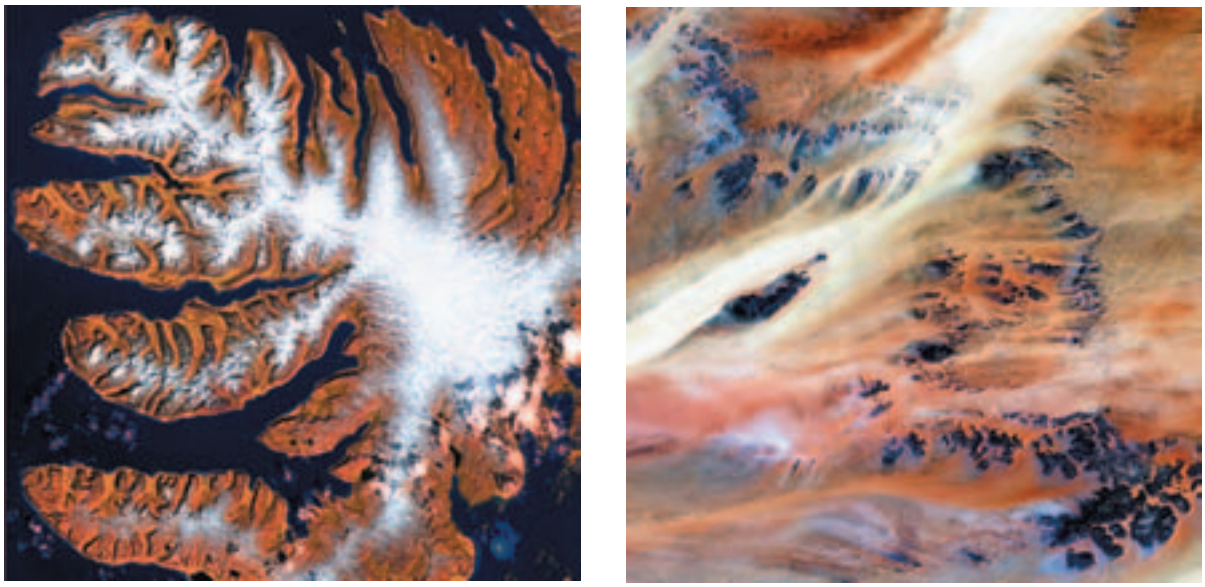

Figure 3. Two Landsat Earth as Art images. (Left) The West Fjords in Iceland. (Right) The Terkezi Oasis in Chad, Africa.

The USGS/NASA EPO team launched Landsat: Earth as Art with a display of a complete set of 41 images in two locations (Library of Congress, and a Science Center in South Dakota affiliated with USGS). A third set of the 41 images were also displayed on a rotational basis at the NASA Headquarters and the NASA Goddard Space Flight Visitors Center. By piloting the images as exhibits in a small number of places, the USGS/NASA team enabled the collection of varied feedback that will allow a decision to be made on expansion of the Earth as Art Program to a national level. The objectives of the Earth as Art pilot exhibits were:

- to increase public appreciation of the USGS/NASA Landsat Program

• to increase the public's general level of knowledge and understanding of viewing Earth from the perspective of space

• to increase public awareness of remote sensing technology

• to introduce teachers and students to the Landsat Program

The pilots also established contacts for development of possible partnerships in future expanded efforts. Currently planned for 2003 are four additional exhibit locations in different regions of the country (Salt Lake City, Utah; Albequerque, New Mexico; Roanoke, Virginia; Lincoln, Nebraska).

Figure 4. The Landsat 7- Earth as Art exhibit at: (left) NASA Headquarters and (right) the Library of Congress.

In conjunction with the pilot exhibits launched in 2002, the Earth as Art web site was developed and placed online. Proving to be a rapid international success, the Earth as Art web site has reached millions of students, teachers, and people of all ages worldwide. From the international success of this new web site, an exhibit was launched in Tel Aviv, Israel in late 2002. To learn more about this exciting program and to view Earth as Art images, visit the Earth as Art website: http://landsat.gsfc.nasa.gov/earthasart/

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Earth as History

On the heels of the success of the Earth as Art Program, the concept for a new program known as Earth as History was developed in 2002. A collaborative project in which major federal agencies will publicize the value of maps, aerial photography, and satellite imagery for the study of history, the Earth as History Program is still in the development stages. The intended audience of this program is the general public, educators, and students of all ages.

Historical research and the study of history can both benefit when satellite imagery, aerial photography, and maps serve as source material. While many scholars, students, and teachers understand the value of historical maps, in general they tend to appreciate aerial photography and satellite imagery less as tools in historical research.

While it is true that aerial photography and satellite imagery are relative newcomers compared to traditional maps, both forms of earth observation have recorded the world during a very pivotal time in history…the twentieth century. Aerial photography has been a viable technology with a well-defined scientific foundation since approximately 1920. Satellite imagery became a major tool in 1972 with the launch of ERTS, the first of today's Landsat platforms.

To commence the Earth as History Program, an educational World Wide Web site and exhibits will be launched in 2003. The goal of the program (both via the web site and exhibits) will be to illustrate the ways in which the three geographic technologies illuminate historical studies.

Initially, the theme of urbanization and forces that shape cities will take the audience on journeys of exploration through historical maps, aerial photographs, and satellite images. In its first phase, the project will feature the growth of four American urban areas: New York, St. Louis, Las Vegas, and Honolulu. The cities of Rome, Cairo, Lima, and Tokyo will be utilized to represent international urbanization.

Earth as History web sites and exhibits will include reproductions of maps, aerial photographs, and satellite images. Short narrative texts, captions, and diagrammatic maps will support the images and place each in context. This interpretive material will contribute basic themes about forces that shape urban change.

Earth as History funding will be sought in the future to:

(1) develop lesson plans, activities, and curriculum support that will help educators incorporate the material from the web sites and exhibits into classroom activities;

(2) create multiple copies of the exhibits, which can travel to schools, libraries, museums, and other educational and cultural institutions.

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MOLA: Models of Earth and Mars Topography for Classroom Use

"Exploring Planetary Topography in the Classroom Using 3-Dimensional Models" is the title of a Director's Discretionary Fund proposal won by John Keller of Code 691 and four Code s921 co-investigators in 2002. Susan Sakimoto, Stephanie Stockman, Jim Roark and Herb Frey provided expertise in Earth and Mars geology, use of MOLA and Earth-based topographic data, and educational outreach using planetary analogs. Keller generated a number of example models for display at both the DDF presentation and at the Fall Geological Society of America (GSA) meeting. Figure 6 shows one such set of models, for the volcano comparison between Olympus Mons (Mars) and the Hawaiian Islands on the Earth, as shown in Figure 5. The vertical exaggeration is the same for both models, in this case, 7x the horizontal scale. The huge volume of Olympus Mons is greater than the volume of the Hawaiian Islands combined.

The DDF proposal is to develop teacher kits and lesson plans around comparative features on the two planets. These will include volcanoes, rift canyons, large river systems, polar caps, and other structures which permit discussion of the measurement and use of topographic data in understanding geologic processes, and how those processes can be similar or different on different planets. The models and lesson plans will be tested out in classrooms by teachers in Sakimoto's course "Teaching the Solar System" in the Spring of 2003 at Johns Hopkins University.

Keller is an expert in the production of plastic models of spacecraft parts and planetary surface features. The same plastic extrusion device obtained to support mission development work can

be used to make 3-dimensional models of volcanoes, river valleys, impact craters and other features - provided a really good topography data set exists. MOLA (Mars Orbiting Laser Altimeter) has provided such data for Mars and comparable data exists for many parts of the Earth. So it is possible to make high accuracy topographic maps of surface features of interest. Figure 5 shows such views for the large Valles Marineris rift canyons of Mars compared to the East African Rift Valleys on Earth, and the largest volcano on Mars compared with the Hawaiian Islands. But flat views, even in perspective, do not fully convey the volumetric aspects of such objects. This is where models, like those of volcanoes at the right, can be useful.

The models were displayed at the Fall meeting of the Geological Society of America Meeting (GSA) by the Planetary Geology Division, of which Sakimoto is president. At the GSA, a visually impaired undergraduate took advantage of the models (below). The models were displayed at the Geological Society of America meeting in Denver, CO. Being 3-dimensional and solid allows exploration of the topography by touch for those who cannot see.

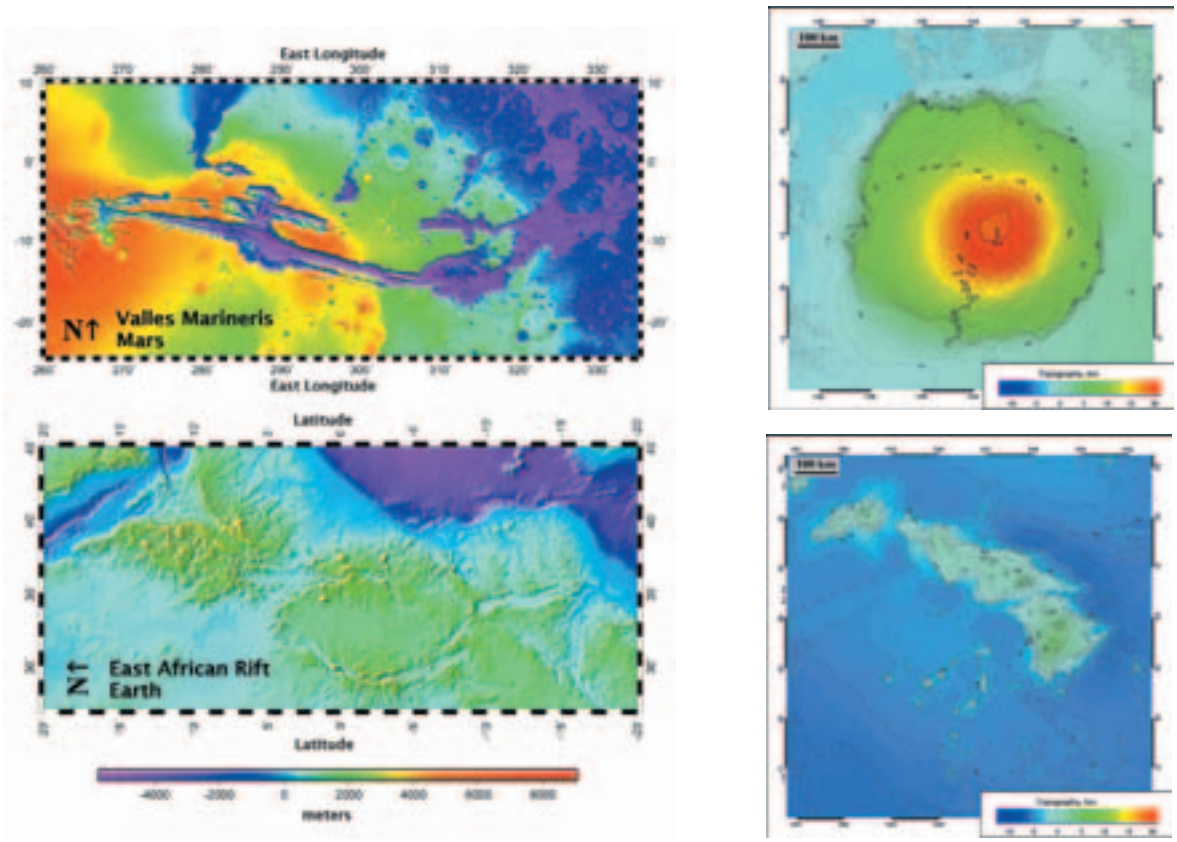

Figure 5. Topographic renditions of the Valles Marineris rift canyons on Mars (upper left) compared to the East African Rift Valley systems on Earth (lower left) at the same spatial scale and with the same topographic scale. The martian canyons are much, much deeper. On the right are compared the largest volcano on Mars, Olympus Mons (upper right), with the Hawaiian Islands on Earth (lower right).

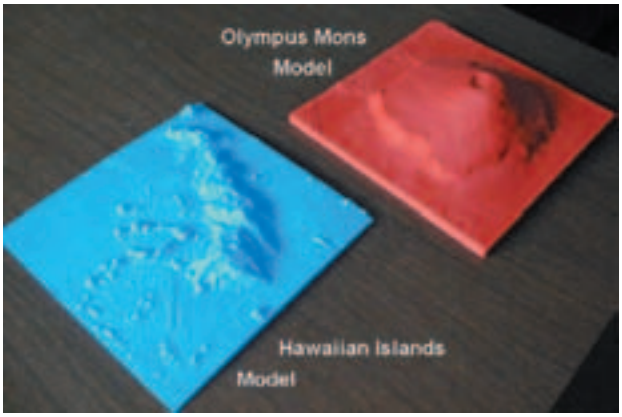

Figure 6. Models of volcanoes on Earth (Hawaiian Islands in blue, lower left) and on Mars (Olympus Mons, in red, upper right). The models have the same spatial scale and the same vertical exaggerations (here, 7x horizontal). Each is about 8 inches on a side.

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Classroom Activity Development

In conjunction with several of the EPO Program projects highlighted above, classroom activities were developed in 2002 to further expand the educational value of programs where appropriate. Specifically, the following classroom activities were developed and are due to be launched in 2003:

• *Bumpy, Wrinkled, Smooth: How Our Earth Looks from Space*. A supplemental activity to the Echo the Bat Web site, this activity can be used in both formal and informal education mediums for grades K-4.

• *Number to Pictures: How Satellite Images are Created.* A supplemental activity to the Echo the Bat Web site, which can be used in both formal and informal education mediums for grades 5-8.

• *Global Tectonic Activity Map litho*, highlights a new global plate tectonic map from Dr. Paul Lowman's research with a classroom activity.

• *Finding Impact Craters with Landsat.* This classroom activity is a demonstration for grades 5-8 on the understanding of the role of impact events in shaping the Earth. Students write a series of guidance questions for a field expedition to determine whether or not a given landform is an impact crater.

• *An Introduction to Remote Sensing and Landsat,* covering fundamental ideas about remote sensing and its applications; where remote sensing fits in the curriculum; investigations that students can carry out with remote sensing; how Landsat's multispectral instrument works; and how teachers can use Landsat in the classroom. Currently available as a PowerPoint presentation on http://landsat.gsfc.nasa.gov

For more information on Landsat's classroom activities please contact: Stephanie Stockman, stockman@core.gsfc.nasa.gov

Website Development

Expanded greatly in 2002, the Laboratory for Terrestrial Physics' web site continues to grow today. A "one-stop" resource for all the Lab's activities, this web site has continued to prove to be a key element in the EPO Program. The crucial role of the Lab's web site in the success of EPO Programs such as Landsat: Earth as Art cannot be overstated. As educational and outreach programs continue to expand, the further development of the web site will continue to allow EPO Programs and products to reach a global audience. In 2003, look for an updated and streamlined web site of resource materials, articles on recent scientific research, more classroom activities, and the utilization of established public and private sector web sites to promote the Lab's achievements. Visit our sites listed below to learn more:

Laboratory for Terrestrial Physics (LTP) Main Page: http://ltpwww.gsfc.nasa.gov/

LTP Education and Public Outreach (EPO) Main Page: http://ltp-education.gsfc.nasa.gov/

Contact: Maggie Masetti, mmasetti@ltpmail.gsfc.nasa.gov

Other Projects

Additionally, the following EPO projects currently under development commenced in 2002:

• New Laboratory for Terrestrial Physics Brochure: A new Laboratory brochure for public outreach is being developed to highlight current projects, past achievements, and resources available.

• Documentary: Currently under production, this documentary highlights the developmental stages of the MESSENGER Mission. Ongoing project that will continue until launch date in March 2004

• GLAS and MOLA Websites: New websites are under development that incorporate and present the Lab's research to a general public audience. These sights are being developed for user friendly navigation for resource and educational information. These web sites will be available in the Spring of 2003: http://glas.gsfc.nasa.gov and http://mola.gsfc.nasa.gov.

For more information on the Laboratory's EPO Program please contact: MK Richardson, mkrichardson@ltpmail.gsfc.nasa.gov

Acknowledgements

The Laboratory for Terrestrial Physics would like to recognize its members for their hard work and accomplishments. This report is proof of the outstanding work they do.

We'd like to thank the Goddard, national, and international communities for their contributions and collaborations with us. We'd like to especially recognize the Massachusetts Institute of Technology (MIT), Scripps Institute of Oceanography, the University of Maryland (UMD) College Park and Baltimore campuses, and the Earth Resources Observation Systems (EROS) Data Center (EDC) for their collaborative efforts.

We would like to thank all who took time from their busy schedules to contribute to this report, especially the Branch Heads and their teams. Special thanks to Charlie Schnetzler for organizing the publications and for sharp eyes while editing. Our thanks go out to the Branch and Office secretaries and administrators.

Thanks go to Maggie Masetti who organized, complied, formatted, edited, and did the layout of the report. Thanks to MK Richardson whose editorial expertise and hard work helped the text of the report to flow smoothly.

Appendix 1 - Acronyms

AERONET	Aerosol Robotic Network
ALI	Advanced Land Imager
APD	Avalanche photodiode
AVHRR	Advanced Very High Resolution Radiometer
BARC	Beltsville Agricultural Research Center
BioSAR	Biological Synthetic Aperture Radar
BKG	Bundesamt fuer Kartographie und Geodaesie
BSDF	Bi-directional Scatter Distribution Function
BRDF	Bi-directional Reflectance Distribution Function
CCD	Charged Coupled Device
CCRS	Canadian Center for Remote Sensing
CDDIS	Crustal Dynamics Data Information System
CF	Calibration Facility
CIESIN	Center for International Earth Science and Information Network
CHAMP	CHAllenging Mini-Satellite Payload
CMB	Core-Mantle Boundary
DAAC	Distributed Active Archive Center
DCaF	Diffuser Calibration Facility
DFB	Distributed FeedBack
DLR	Deutsche Zentram Fur Luftund Raumfahrt
DMSP/OLS	Defense Meteorological Satellite Programs Operation Linescan System
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DSN	Deep Space Network
EDC	EROS Data Center
ENVISAT	ENVIronmental SATellite
EO-1	Earth Observing One (satellite)
EOS	Earth Observing System
EPSCoR	Experimental Program to Stimulate Competitive Research
EROS	Earth Resources Observing System
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ESE	Earth Science Enterprise
ESSP	Earth System Science Pathfinder
ETM +	Enhanced Thematic Mapper Plus
FAME	Full-sky Astrometric Mapping Explorer
FWHM	Full Width Half Maximum
GFO	GEOSAT Follow-On
GGFC	Goddard Geophysical Fluids Center
GIMMS	Global Inventory Mapping and Monitoring Studies
GIS	Geographic Information System
GLAS	Geoscience Laser Altimeter System
GLONASS	Global'naya Navigatsionnay Sputnikovaya Sistema (Global Navigation Satellite System)
GOFC/GOLD	Global Observation of Forest and Land Cover Dynamics
GPS	Global Positioning System
GRACE	Gravity Recovery And Climate Experiment
GSFC	Goddard Space Flight Center
HSI	HyperSpectral Imager
IAG	International Association of Geodesy
IDS	International DORIS Service
IEEE	Institute of Electric & Electronics Engineers
IERS	International Earth Rotation Service

IGS	International GPS Service
ILRS	International Laser Ranging Service
INDOEX	Indian Ocean Experiment
IVS	International VLBI Service for Geodesy and Astrometry
JIVE	Joint Institute for VLBI in Europe
KTP	Potassium (K) Titanate (Ti) Phosphate (P)
KVN	Korean VLBI Network
LAI	Leaf Area Index
LBA	Large-Scale Biosphere-Atmosphere Experiment in Amazonia
LCLUC	Land-Cover Land-Use Change
LDCM	Landsat Data Continuity Mission
LDOPE	Land Data Operational Product Evaluation
LEO	Low Earth Orbiter
LLR	Lunar Laser Ranging
LTP	Laboratory for Terrestrial Physics
MBLA	Multi Beam Laser Altimeter
MCST	MODIS Characterization Support Team
MFF	Medusae Fossae Formation
MGS	Mars Global Surveyor
MISR	Multi-angle Imaging SpectroRadiometer
MLA	Mercury Laser Altimeter
MLL	Mixed Layer Lidar
MOBLAS	Mobile Laser Ranging Stations
MOC	Mars Orbiter Camera
MODAPS	MODIS Adaptive Processing System
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPITT	Measurements Of Pollution In The Troposphere
MOSST	MOdular, Scalable, Self-consistent, Three-dimensional
MPIR	Max Planck Institute for Radioastronomy
NCEP	National Center for Environmental Predictions
NDVI	Normalized Difference Vegetation Index
NEIGE	NetLander Ionospheric and Geodesic Experiment
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRAO	National Radio Astronomy Observatory
NRL	Naval Research Laboratory
NTIA	National Telecommunications and Information Administration
OMI	Ozone Measuring Instrument
ORNL	Oak Ridge National Lab
POD	Precision Orbit Determination
PRIDE	Puerto Rico Dust Experiment
RAID	Redundant Array of Inexpensive Disk
RASL	Raman Airborne Spectroscopic Lidar
RVF	Rift Valley Fever
SAFARI	Southern Africa Regional Science Initiative
SAVE	Southern Africa Validation of EOS (SAVE
SAR	Synetic Aperture Radar
SeaWifs	Sea-viewing Wide Field-of-view Sensor
SDP	Scientific Data Purchase
SLA	Shuttle Laser Altimeter
SLR	Satellite Laser Ranging
STARSHINE	Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment

STRI	Smithsonian Tropical Research Institute
TEC	Total Electron Content
TOPEX	Ocean TOPography EXperiment
TOMS	Total Ozone Mapping Spectrometer
TRF	Terrestrial Reference Frame
USDA	United States Department of Agriculture
UNFAO	United Nations Food and Agriculture Organization
USGCRP	U.S. Global Change Research Program
USNO	United States Naval Observatory
USUHS	Uniformed Services University of the Health Sciences
VCL	Vegetation Canopy Lidar
VHF	Very High Frequency
VLBI	Very Long Baseline Interferometry

Appendix 2 - Grants, Contracts, Co-operative Agreements

The Laboratory for Terrestrial Physics has many efforts that involve sources of information, areas of study, and co-operations housed within, and external to, the physical confines of the Laboratory.

Grants are generally established with colleges and universities. The Laboratory has established grants or contracts totaling nearly $36M with 54 institutions of higher education, involving nearly 200 students and professors. Among those institutions involved are:

University of Alabama
University of Alaska
University of Arizona
Auburn University
Boston University
Bowie State University
Brown University
University of California
California Institute of Technology
University of California, Berkeley
University of California, Irvine
University of California, Los Angeles
University of California, San Diego
University of California, Santa Barbara
Calvin College
University of Colorado
Columbia University
Cornell University
University of South Florida
Florida State University
University of Hawaii
Harvard University
University of Indiana
Johns Hopkins University
Louisiana State University

University of Maryland, Baltimore Campus
University of Maryland, College Park
University of Massachusetts
Massachusetts Institute of Technology
University of Miami
University of Michigan
Michigan State University
University of Missouri
University of Montana
University of Nevada, Reno
University of New Hampshire
State University of New York
University of North Carolina
Northwestern University
Oregon State University
Pennsylvania State University
University of Pittsburgh
Rochester Institute of Technology
South Dakota State University
Stanford University
University of Texas
University of Utah
University of Virginia
University of Washington
Central Washington University
University of Wisconsin

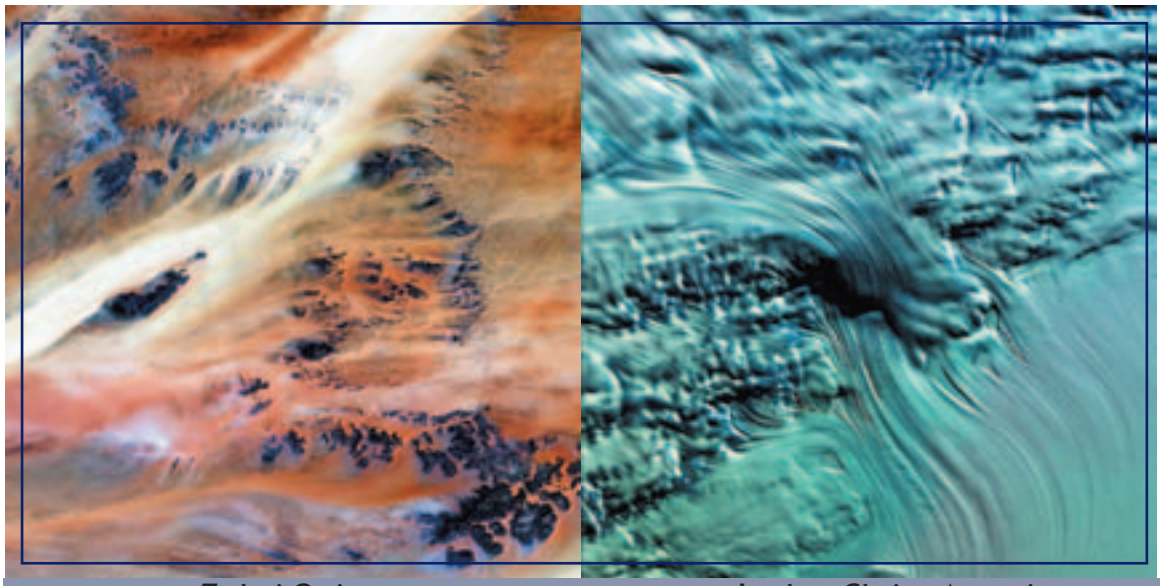
The Laboratory is responsible for grants with 3 commercial industries:

G. O. Logic
Analytical Imaging and Geophysics LLC
AER, inc.

The Laboratory holds cooperative agreements with 11 institutions, with over 30 people involved:

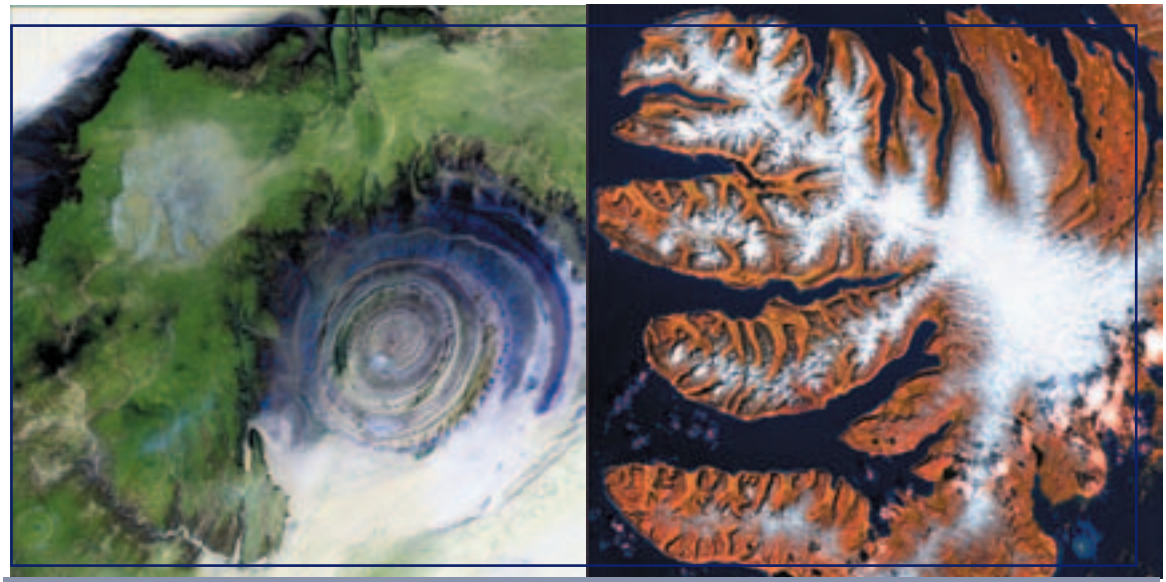
U.S. Department of Agriculture
UNSA (Peruvian Space Agrncy)
Desert Research Institute
Environmental Protection Agency
U.S. Geological Survey
Marine Biological Laboratory
National Center for Atmospheric Research
National Oceanic and Atmospheric Administration
Scripps Institute of Oceanography
Smithsonian Institution
Woods Hole Oceanographic Institute

Additionally, performance-based contracts are held with a number of commercial service providers. Among these are: General Sciences Corp., Global Science and Technology, Honeywell Technology Solutions, NVI, Raytheon, Science Systems and Applications, Inc., and Sigma Research.



Terkezi Oasis

Lambert Glacier, Antarctica



Richat Structure

West Fjords, Iceland

NP-2003-5-550-GSFC